Research Article

SCISET
www.sciset.com

Journal of Geology, Earth and Marine Sciences

2023
Vol. 1 No. 1: 102

Enhancing Hydrocarbon Field Recovery: Employing Multi-Stage Hydraulic Fracturing (MSHF) for the Development of Low-Permeability Deep-Lying Deposits

Sudad H. Al-Obaidi*

Mining University, Saint Petersburg, Russia

Corresponding author:
Sudad H. Al-Obaidi, Mining University, Saint Petersburg, Russia. E-mail: Sudad_AIO@gmail.com

Citation: Al-Obaidi SH. (2023) Enhancing Hydrocarbon Field Recovery: Employing Multi-Stage Hydraulic Fracturing (MSHF) for the Development of Low-Permeability Deep-Lying Deposits. J Geol Earth Mar Sci. Vol 1(1): 102.

Received: March 12, 2023; **Accepted:** March 27, 2023; **Published:** April 05, 2023

Abstract

The development of deep-lying deposits offers the opportunity to extract additional volumes of gas and gasoline from fields experiencing declining production. This necessitates the introduction of new production methods to address decreased productivity in gas condensate fields. Hydraulic Fracturing (HF) emerges as a crucial method for intensifying production, particularly in low-permeability deep deposits. This study focuses on the application of Multi-Stage Hydraulic Fracturing (MSFH) as a highly effective technique for enhancing gas and condensate production in deep deposits with low permeability. Two distinct hydraulic fracturing processes were employed: Large-volume hydraulic fracturing, involving the injection of 300 tons of proppant, and HiWay hydraulic fracturing, with 200 tons of proppant injection. The study reveals that HiWay technology significantly reduces proppant requirements for securing hydraulic fractures, achieving a reduction of up to 38.5% compared to high-volume technology. Following the implementation of these geological and technical measures, a noteworthy 2.5-fold increase in flow rate is observed at wells in the deep-lying deposits of the studied field. Furthermore, the hydraulic fracturing effect endures for a substantial three-year period.

Keywords: Multi-Stage Hydraulic Fracturing (MSFH); Deep-lying deposits; Low-permeability; Proppants; HiWay technology.

Introduction

The continuous advancement of technologies for enhancing reservoir fluid inflows and optimizing well completion stands as a pivotal approach to sustaining profitable levels of oil and gas production [1-4]. In the context of stimulating inflow in a hydrocarbon field characterized by low-permeability reservoir rocks, the application of Multi-Stage Hydraulic Fracturing (MSHF) technology proves instrumental, particularly in the completion of horizontal and directional wells. This study explores two variations of multi-stage hydraulic fracturing, with the first employing Hydraulic Fracturing (HF) technology through the deployment of lowering packer assemblies [5-9].

In the first hydraulic fracturing method, a specialized device is lowered into the well, executing multiple fractures in the horizontal, cemented part of the column. This process induces an inflow of hydrocarbons from the productive formation. The second hydraulic fracturing method involves an assembly equipped with burst couplings and casing packers, which is lowered into the horizontal section of the wellbore to isolate hydraulic fracturing intervals (see Figure 1). As hydraulic fracturing fluid is pumped, soluble balls of predetermined diameters are introduced, initiating the opening of rupture couplings when seated in their saddles. This allows communication with the productive formation, facilitating hydraulic fracturing.

To activate subsequent burst sleeves for additional hydraulic fracturing intervals after the initial stage, soluble balls with progressively increasing diameters are introduced into the liquid. This repetitive release of balls ensures the activation of all rupture couplings, guaranteeing planned multi-stage hydraulic fracturing in the horizontal well section [10-13].

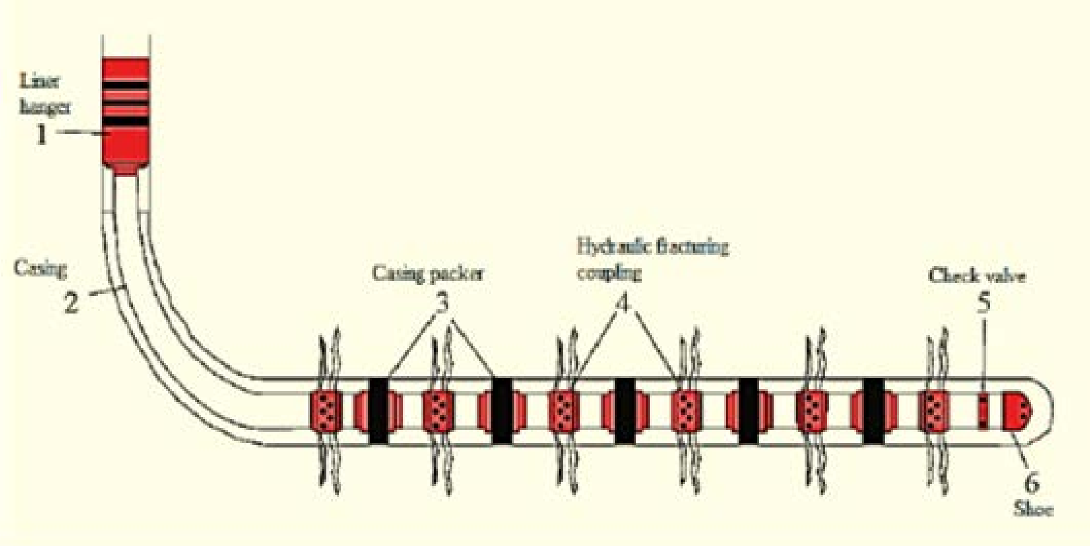

Figure 1: Layout for hydraulic fracturing with burst couplings and casing packers.

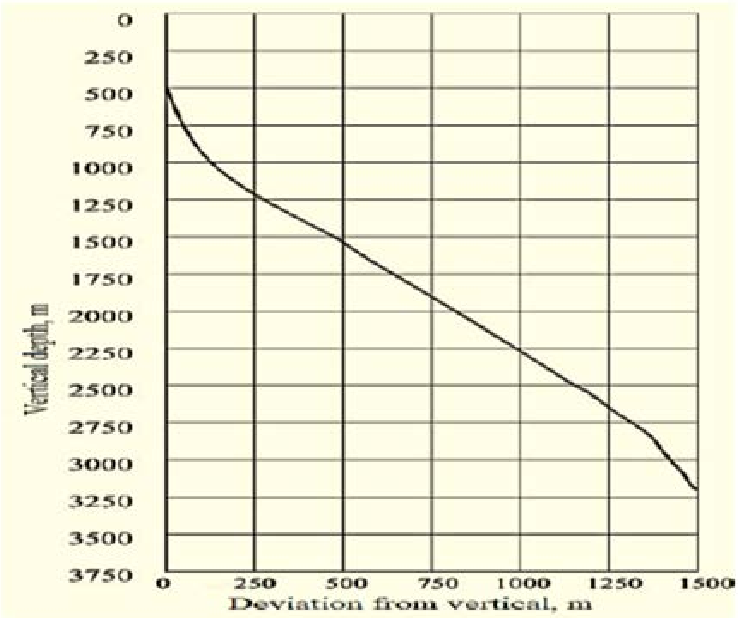

Figure 2: Profile of an S-shaped production well.

The multi-stage hydraulic fracturing method implemented in the studied hydrocarbon field involves three to seven stages, effectively creating fracture systems to enhance hydrocarbon flow.

Materials and Methods

The development of deep-lying deposits presents an opportunity to extract additional hydrocarbon volumes from gas fields amidst declining production, necessitating the introduction of new methods to enhance oil, gas, and condensate production [14-17]. The focus of this study is on an oil and gas condensate field where the content of hydrocarbons in productive formations, spanning from Cenomanian to Lower Jurassic deposits, is examined. Notably, oil rims are observed along the edges of these deep-lying deposits (Figure 2).

Geological exploration data reveal a lens-shaped, discontinuous distribution of layers within these deposits, formed under avalanche sedimentation conditions and representing fondomorphic parts of Valanginian clinoform complexes [18-21]. The field comprises several bearing formations, denoted as A1-2, A3-4, A4, and A5, with the most significant productivity observed in A3-4 and A5. The permeability of these complex reservoirs ranges from 1.0×10^{-3} μm² to 10.0×10^{-3} μm², displaying fractured and porous-fractured reservoir types [22-25].

The sandy-shaly deposits are overlain by Lower Valanginian clays and mudstones, ranging from 150 m to 300 m in thickness. Field development commenced in 2013, with priority given to the gas condensate deposits of the A3-4 and A5 formations. The A1, A2, and A6 formations are secondary targets due to limited knowledge, slated for development in subsequent phases [26].

Four oil and gas condensate objects have been identified within the studied field, categorized as formations A1 and A2, A3-4, A5, and A6. Three types of wells—vertical, S-shaped, and sub-horizontal—are recommended for development, reaching depths of 4,194 m and 4,517 m for S-shaped and sub-horizontal wells, respectively [27].

For effective reservoir development, liners are run at intervals of 3,490 m up to 3,770 m and 3,904 m to 4,194 m in wells with an S-shaped profile. In sub-horizontal wells, liner intervals range from 3,430 m to 3,740 m and 3,782 m to 4,517 m. Liners are utilized to isolate and develop productive formations, secured with cement mortar along their entire length in vertical wells and from the top of the productive formation to the liner hanger in sub-horizontal wells (Figure 3).

Production casing is deployed to cover Neocomian sediment layers and transitional unstable zones, with casing depths varying vertically and along the wellbore based on well profiles [28]. In the Cenomanian deposits interval, absorption of drilling fluid is addressed by lowering an intermediate column, allowing for geophysical investigations while preventing fluid absorption. The distance between the bottoms of production wells ranges from 1,200 m to 1,700 m in production areas, contingent on the distribution of gas-saturated thicknesses in the deposits.

Results and Discussion

The development of deep-lying deposits presents an avenue for extracting additional volumes of gas and condensate from fields experiencing declining production, categorizing these deposits as hard-to-recover reserves. To effectively unlock their potential, hydraulic fracturing (HF) emerges as a pivotal method for enhancing hydrocarbon influx from low-permeability reservoirs [29].

The strategic use of Hydraulic Fracturing (HF) as a primary method for field development, rather than merely for individual wells, significantly enhances efficiency. The success of HF is contingent upon optimal hydraulic fracturing programs, considering the size and orientation of formation fractures within oil and gas field development systems [30].

The design of hydraulic fracturing is grounded in geological and geophysical studies, incorporating well design and operational data. Successful hydraulic fracturing is gauged by the hydrodynamic connection between the well and the formation, ultimately determining well productivity [31]. Assessment of the hydraulic fracturing process involves comparing productive characteristics before and after implementation.

Calculations indicate that hydraulic fracturing alters the direction of fluid flows and the accumulation of retrograde condensate in

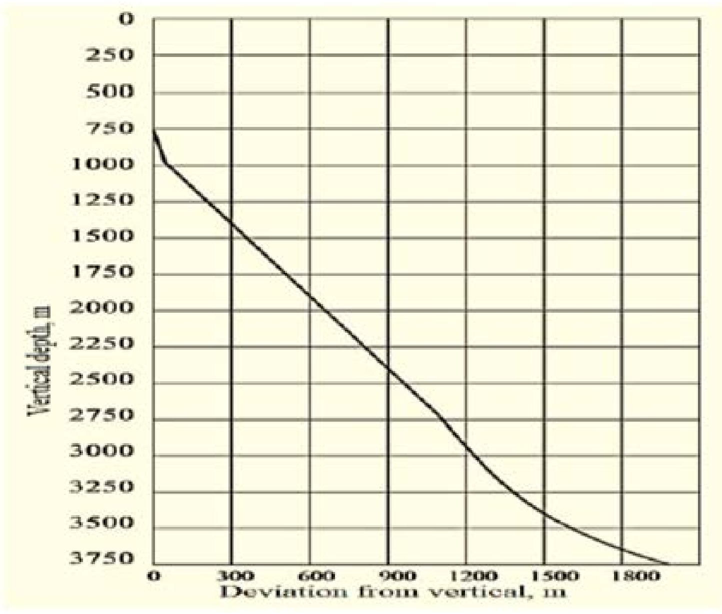

Figure 3: Profile of a production sub-horizontal well.

the bottom-hole zone. The efficiency of hydraulic fracturing in gas condensate formations is influenced by the relative phase permeabilities of reservoir rocks and hydraulic fractures. If the hydraulic fracture's permeabilities are higher than the formation's average, gas condensate well efficiency surpasses that of gas wells; conversely, lower hydraulic fracture permeabilities result in reduced efficiency [32].

Hydrodynamic studies in wells penetrating A3-4 and A5 formations in the studied field revealed dependencies on penetration type, well completion, and stimulation method (Table 1). Of the 62 production wells in the deep-lying deposits, nine and 50 hydraulic fracturing operations were performed in the A3-4 and A5 formations, respectively. Over half utilized high-volume hydraulic fracturing, while 24 employed HiWay technology. Proppants, including BorProp 20/40 and Fores 20/40, formed fracture internal structures, while ForesRCP 16/20 and ForesRCP 20/40 secured fractures near the wellbore.

The well-testing analysis demonstrated the effectiveness of hydraulic fracturing, with almost all wells achieving or exceeding expected gas condensate flow rates. Post-fracturing well logging revealed gas-releasing intervals concentrated at the roof of productive formations (Figure 4).

The field employed two hydraulic fracturing technologies—large-volume hydraulic fracturing (up to 300 tons of proppant) and HiWay technology (exceeding 200 tons). HiWay, designed for highly conductive fractures, notably reduced proppant mass compared to high-volume hydraulic fracturing [33]. The use of structure-forming material J954 further contributed to fracture creation. Consequently, HiWay technology significantly reduced proppant mass, as illustrated in Figure 5.

Following these geological and technical interventions, a 2.5-fold increase in flow rate was observed in the wells of the deep-lying deposits, with the hydraulic fracturing effect enduring for three years.

Table 1: The average operating parameters of wells with different penetration types.

Type of opening	Type of HF	Number of wells	Average flow rate of wells, 1000 m^3/day	Drawdown reservoir pressure, MPa	Average productivity, 1000 m^3/day/MPa^2	Average condensate-gas factor (GOR), g/m^3
Vertical	Without HF	2	257	9,0	0,3	458
Vertical	HF	31	751	11,0	0,8	395
Horizontal	Without HF	1	950	13,0	0,8	356
Sub-horizontal	Without HF	14	759	11,0	0,7	361
Sub-horizontal	HF	1	850	12,0	0,6	400
Sub-horizontal	MSFH	6	1346	5,0	2,7	396

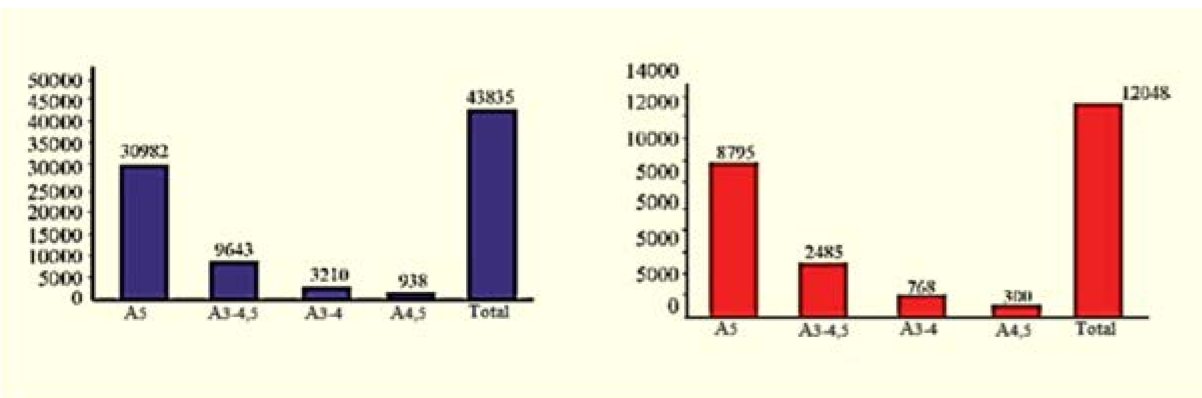

Figure 4: Mass distribution of proppant injected into hydraulic fractures.

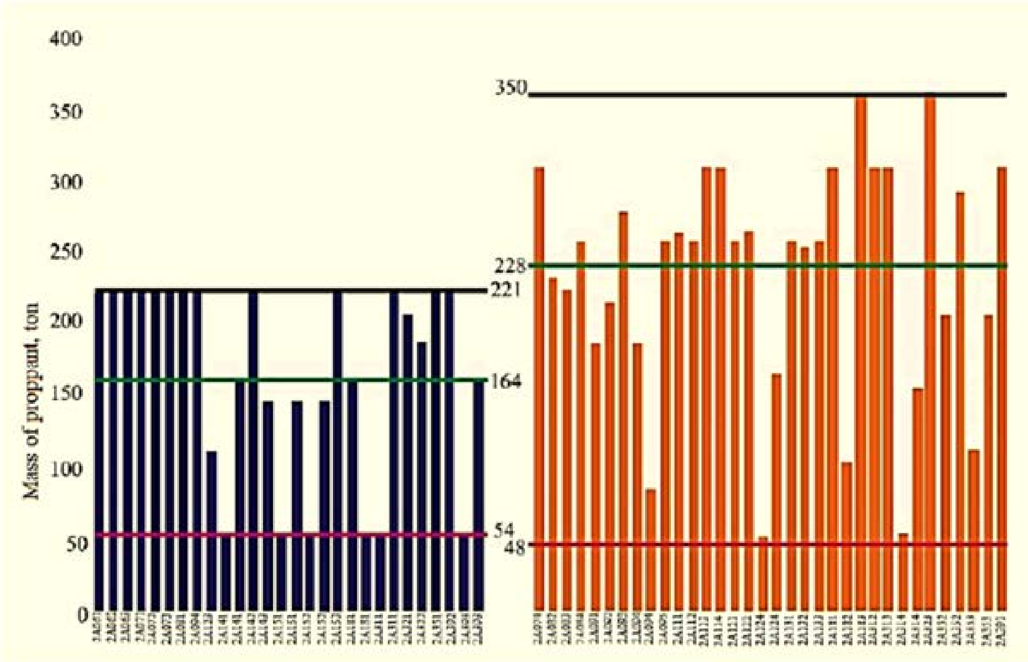

Figure 5: Comparative analysis of proppant mass using HiWay technology and high-volume hydraulic fracturing technology.

Conclusion

In the realm of low-permeability and deep-laying deposits, Multistage Hydraulic Fracturing stands out as a potent tool for creating expansive, permeable fractures. Its efficacy lies in preserving the reservoir rock's flow characteristics around fractures, thereby establishing favorable conditions for the inflow of gas and condensate into the wellbore.

An examination of well productivity in the studied low-permeability and deep-lying deposits revealed that the A5 and A6 formations exhibit lower reservoir properties than the A3-4 formations. Despite this, the A5 and A6 formations are crucial production targets due to their condensate yields, which are twice as high as those from the A3-4 formation at comparable bottom-hole pressures.

Comparatively, HiWay technology proves advantageous over high-volume technology, notably reducing the proppant required to secure hydraulic fractures by less than 38.5%. In the deep-lying, low-permeability deposits of the studied field, hydraulic fracturing maintains its effectiveness for three years following the implementation of technical and geological measures, resulting in a 2.5-fold increase in flow rate.

References

1. Verisokin AE, Shlein GA, Dimitriadi YK. Combined technological solutions to increase inflow in oil wells of offshore fields. In IOP Conference Series: Earth and Environmental Science. 2021;872(1):012012.
2. Al-Obaidi SH. Improve the efficiency of the study of complex reservoirs and hydrocarbon deposits-East Baghdad Field. Int J Sci Technol Res. 2016; 5(8),129-131.
3. Miel H, Hameed AO, Hussein KF. Modeling and monitoring the development of an oil field under conditions of mass hydraulic fracturing. Trend Sci. 2022;19(8):3436.
4. Al-Obaidi SH, Kamensky IP, Hofmann M. Changes in the physical properties of hydrocarbon reservoir as a result of an increase in the effective pressure during the development of the field. engrXiv. 2010.
5. Leontiev D, Shamsutdinov N, Vaganov Y, Shalyapina A, Shalyapin D, Zhigalkovskaya M. Multi-stage hydraulic fracturing technology in a well with horizontal working face. Earth Sci Bull. 2022;52:9-17.
6. Al-Obaidi SH. Analysis of hydrodynamic methods for enhancing oil recovery. J Petrol Eng Tech. 2021; 6:20-26.
7. Smirnov VI, Al-Obaidi Sudad H. Innovative methods of enhanced oil recovery. Oil Gas Res. 2008;1:101.
8. Al-Obaidi SH, Kamensky IP, Hofmann M, Khalaf FH. An Evaluation of water and gas injections with hydraulic fracturing and horizontal wells in oil-saturated shale formations. Nat Sci Adv Technol Edu. 2022;31(4).
9. Chang W, Al-Obaidi SH. Evaluation of the quantitative criteria of Triassic carbonate rocks reservoirs. J Geol Geophys. 2023;12.1067.
10. Speight JG. Handbook of hydraulic fracturing. John Wiley and Sons; 2016.
11. Al-Obaidi SH, Khalaf FH. Development of traditional water flooding to increase oil recovery. Int J Sci Technol Res. 2019; 8(1):177-181.

12. Chang WJ, Al-Obaidi SH, Patkin AA. The use of oil-soluble polymers to enhance oil recovery in hard to recover hydrocarbons reserves. Int Res J Mod Eng Technol Sci. 2021;3(1):982-987.

13. Al-Obaidi SH. High oil recovery using traditional water-flooding under compliance of the planned development mode. J Petrol Eng Technol. 2016;6(2),:48-53.

14. Skiba AK. Construction of a gas condensate field development model. Open Comput Sci. 2022;12(1):103-111.

15. Al-Obaidi SH, Khalaf FH, Smirnov VI. New technologies to improve the performance of high water cut wells equipped with ESP. Technium. 2020;3(1)104-113.

16. Kamensky IP, Al-Obaidi SH, Khalaf FH. Scale effect in laboratory determination of the properties of complex carbonate reservoirs. Int Res J Mod Eng Technol Sci. 2020;2(11):1-6.

17. Al-Obaidi SH, Khalaf FH. Acoustic logging methods in fractured and porous formations. J Geol Geophys. 2017;6(4):2.

18. Gao H, Wu X, Zhang J, Sun X, Bi Z. ClinoformNet-1.0: Stratigraphic forward modeling and deep learning for seismic clinoform delineation. Geosci Model Dev. 2023;16(9):2495-2513.

19. Al-Obaidi SH, Kamensky IP. Express study of rheological properties and group composition of oil and condensate using nuclear magnetic resonance–relaxometry. J Oil Gas Coal Technol. 2022;4(1):102.

20. Hofmann M, Al-Obaidi SH, Patkin AA. Problems of transporting “heavy” gas condensates at negative ambient temperatures and ways to solve these problems. J Petrol Eng Technol. 2013;3(3):31-35.

21. Al-Obaidi SH, Guliaeva NI. Determination of flow and volumetric properties of core samples using laboratory NMR relaxometry. J Petrol Eng Technol. 2002;1(2):20-23.

22. Panikarovskiy VV, Panikarovskiy EV, Kleshchenko II. Petro-physical studies of reservoir rocks to increase well productivity. In Development and operation of gas and gas condensate fields. IRC Gazprom. 2006:100.

23. Al-Obaidi SH, Hofmann M, Khalaf FH, Alwan HH. The efficiency of gas injection into low-permeability multilayer hydrocarbon reservoirs. Technium. 2021;3(10):100-108.

24. Patkin A, Al-Obaidi S. Influence of temperature and pressure of incoming oil-containing liquid from field wells on the gas separation process. J Petrol Eng Emerg Technol. 2001;3(4):20-24.

25. AL-Obaidi SH, Wj C, Hofmann M. Modelling the development of oil rim using water and gas injection. Nat Sci Adv Technol Edu. 2022;31(3).

26. Prischepa O, Nefedov Y, Nikiforova V. Arctic shelf oil and gas prospects from lower-middle paleozoic sediments of the timan–pechora oil and gas province based on the results of a regional study. Resources. 2021;11(1):3.

27. AL-Obaidi SH, Hofmann M, Smirnova V. Improvement of oil recovery in hydrocarbon fields by developing polymeric gel-forming composition. Nat Sci Adv Technol Educ. 2022;3:425-434.

28. Hofmann M, Al-Obaidi SH, Chang WJ. Evaluation of quantitative criteria for triassic reservoirs in the South Mangyshlak basin. Nat Sci Adv Technol Educ. 2023;32(1):7-24.

29. Al-Obaidi SH, Khalaf FH. A new approach for enhancing oil and gas recovery of the hydrocarbon fields with low permeability reservoirs. Pet Petro Chem Eng J. 2023;7(2):000343.

30. El Sabeh K, Gaurina-Međimurec N, Mijić P, Medved I, Pašić B. Extended-Reach Drilling (ERD)—The main problems and current achievements. Appl Sci. 2023;13(7):4112.

31. Al-Obaidi SH. A way to increase the efficiency of water isolating works using water repellent. Int Res J Modern Eng Technol Sci. 2020;2(10):393-399.

32. Chang WJ, Al-Obaidi SH, Patkin AA. Assessment of the condition of the near-wellbore zone of repaired wells by the skin factor. Int Res J Mod Eng Tech Sci. 2021;3:1371-1377.

33. Al-Obaidi S, Hofmann M. Prediction of current production rates, cumulative production and recoverable reserves of hydrocarbon fields. OSF Preprints. 2012.